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# Development and Application of a Quality System Standard for Construction Materials Testing Laboratories

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**ABSTRACT:** The American Association of State Highway and Transportation Officials (AASHTO) Accreditation Program (AAP) was initiated by AASHTO in 1988 as a tool for promoting the quality of testing in construction materials laboratories. The program currently has around 120 laboratories accredited for testing of various construction materials. In the program it became apparent that there was a need to provide specific guidance to laboratories in preparing and implementing a quality system. In response, AASHTO prepared Recommended Practice R18-92I, "Establishing and Implementing a Quality System for Construction Materials Testing Laboratories." While generally based on existing ASTM and International Standards Organization (ISO) standards, Practice R18 is much more definitive in regard to evaluation criteria for construction materials laboratories. It includes an appendix that provides illustrated examples of documents, forms, and standard operating procedures, which may be used by the laboratory in preparing a quality manual. Practice R18 has been adopted for use in the AASHTO Materials Reference Laboratory (AMRL) Laboratory Inspection Program, and became mandatory for laboratories participating in the AASHTO Accreditation Program in April 1994. This paper presents an overview of Practice R18 and its use in the AMRL Laboratory Inspection Program and the AASHTO Accreditation Program.

**KEYWORDS:** accreditation, construction materials, laboratory, quality, standards, testing

*The American Association of State Highway and Transportation* Officials (AASHTO) established the AASHTO Accreditation Program (AAP) in 1988 to provide a mechanism for formally recognizing the competency of a testing laboratory to carry out specific tests on construction materials [*1*]. AASHTO is the national association of state departments of highways and transportation with membership from the 50 states, the District of Columbia, and Puerto Rico. The first laboratory was accredited by AASHTO in June 1988 and as of June 1993 there were 116 laboratories accredited [2]. Participation levels by laboratory type and field of test are as follows:

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|---|---|
| Laboratory Type | |
| State Transportation Departments | 26 |
| Materials Producers | 10 |
| Independent Laboratories | 66 |
| Federal Laboratories | 7 |
| Others (Universities, local government, etc.) | 7 |
| Fields of Test | |
| Asphalt Cement | 42 |
| Emulsion | 29 |
| Bituminous Concrete | 78 |
| Bituminous Concrete Aggregate | 81 |
| Soil | 79 |
| Portland Cement Concrete | 74 |
| Portland Cement Concrete Aggregate | 76 |

One of the requirements for a laboratory to obtain accreditation under AAP is that it develop and maintain a quality system. The purpose of this paper is to report on the development and use of AASHTO Recommended Practice R18, "Establishing and Implementing A Quality System for Construction Materials Testing Laboratories" [*3*].

## Need for Quality System Standard

Early experience with laboratories seeking AAP accreditation showed the need for specific criteria relative to the quality system and guidance on how to comply with the criteria. While many laboratories had various components of a quality system, many did not have an organized approach in managing quality. The AASHTO Subcommittee on Materials (ASOM), which has been assigned the responsibility for the operation and management of the AAP by AASHTO, determined that there was a need for a standard to provide definitive quality system criteria, which would assist laboratories seeking accreditation.

The AASHTO Materials Reference Laboratory (AMRL), which provides technical support to the AASHTO Subcommittee on Materials in the operation of the AAP, undertook the task of preparing a draft standard. AMRL is located at the National Institute of Standards and Technology (NIST) under the sponsorship of AASHTO [*4*]. AMRL provides services that promote uniformity of testing of construction materials testing laboratories and assists the transportation industry in obtaining reliable measurements of highway materials properties. These services include laboratory inspection and proficiency sample programs. AMRL visits labora-

TABLE 1—*Description of quality system components in Practice R18* [3].

| Sample | Quality System Component | Description |
|---|---|---|
| 1 | Quality Manual | Laboratory to establish and maintain a quality manual that conforms to requirements in Table 2. |
| 2 | Technical Manager | Technical manager has overall responsibility for technical operations of laboratories. |
| 3 | Quality System Management | Laboratory to have individual with direct access to top management who is responsible for monitoring quality system implementation activities as specified in the quality manual. |
| 4 | Equipment Calibration and Verification | Laboratory to calibrate and verify testing equipment.[a] |
| 5 | Proficiency Sample Testing | Laboratory to participate in applicable Proficiency Sample Program of AMRL and CCRL [4]. |
| 6 | Test Records | Laboratory to maintain test records with sufficient information to permit verification of test reports. |
| 7 | Equipment Records | Equipment calibration and verification records to be maintained for test equipment specified in the quality manual.[b] |
| 8 | Records Retention | Laboratory to maintain pertinent records for at least 3 years. |
| 9 | Test Methods and Procedures | Laboratory to maintain copies of standard and non-standard procedures used in testing. |

[a]Practice R18 provides minimum intervals for typical equipment used in the fields of testing covered in the standard. Figure 1 from Practice R18 provides typical requirements for soil test equipment.

[b]Records include results of work performed, equipment description, date of work, name of individual performing the work, identification of the procedure and in-house equipment used, and next calibration or verification date. Figure 2 is a typical calibration record form in Practice R18, and Fig. 3 is a typical equipment verification record.

TABLE 2—*Description of quality manual requirements in Practice R18* [3].

| Sample | Quality System Component | Description |
|---|---|---|
| 1 | Staff | Manual to contain laboratory organization chart, staff position descriptions and biographical information, and methods for training and evaluating staff. |
| 2 | Equipment | Manual to contain pertinent information on sampling, testing, calibration, and verification of equipment.[a] |
| 3 | Test Report and Records | Manual to contain a description of methods used by the laboratory for producing test results and preparing test reports; and forms illustrating the manner in which test results and supporting information are to be documented. |
| 4 | Sample Management | Manual to contain a description of procedures for identification, storage, retention, and disposal of specimens. |
| 5 | Diagnostic and Corrective Action | Manual to contain a document describing participation in proficiency sample and laboratory inspection program; methods used to identify poor results; and procedures followed when poor results are identified. Figure 5 is a model document in Practice R18. |
| 6 | Internal Quality System Review | Manual to contain a document describing internal quality system reviews, individuals responsible for the reviews, reporting of results to management, and storage location of the records. |
| 7 | Subcontracting | Manual to contain a document describing the policies the laboratory follows relative to subcontracting. |

[a]This includes an inventory and general description; methods used to ensure that calibration and verification procedures are performed at specified intervals; in-house calibration and verification procedures used when not available in applicable standards; and certificates or other documents that establish traceability of calibrations. Figure 4 from Practice R18 is a typical model document on policies and procedures for equipment calibration and verification.

tories that test construction materials approximately every 20 months to evaluate their equipment, test procedures, and quality program. The proficiency sample program includes the distribution of soil, aggregate, asphalt, and bituminous concrete samples. AAP requires laboratories to participate in both programs in order to be accredited. In addition to the support provided by NIST, AMRL receives financial support from the 50 state transportation departments, the Federal Highway Administration, and from laboratories that pay for its services on a fee basis.

As a starting point in the preparation of the standard, AMRL reviewed existing national and international standards related to testing laboratory quality. This included the following ASTM standards:

| | |
|---|---|
| ASTM E 548 | Guide for General Criteria Used for Evaluating Laboratory Competence [5] |
| ASTM C 1077 | Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation [6] |
| ASTM D 3740 | Practice for Minimum Requirements Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction [7] |
| ASTM D 3666 | Specification for Minimum Requirements for Agencies Testing and Inspecting Bituminous Paving Materials [8] |
| ASTM D 4561 | Practice for Quality Control Systems for an Inspection and Testing Agency for Bituminous Paving Materials [8] |

| Equipment - Test Method | Requirement | Interval (Month) |
|---|---|---|
| Mechanical Shakers | Ck. Sieving Thoroughness | 12 |
| Gen. Purpose Balances, Scales & Weights | Verify | 12 |
| Compression or Loading Device - T193, T208, T216, T234, T236, D1883, D2166, D2435, D2850, D3080 | Verify Load Indications | 12 |
| Mechanical Compactor - T99, T180, D698, D1557 | Calibrate | 36 |
| CA Kneading Compactor - T190, D2844 | Calibrate | 24 |
| Ovens | Verify Temperature Setting(s) | 4 |
| Vacuum System - T100, D854 | Ck. Pressure | 24 |
| Molds - T99, T134, T135, T136, T180, T190, T193, D698, D558, D559, D560, D1557, D1883, D2844 | Ck. Critical Dimensions | 12 |
| Manual Hammer - T99, T180, D698, D1557 | Ck. Wt. & Critical Dimensions | 12 |
| Sieves | Ck. Physical Condition | 6 |
| Liquid Limit Device - T89, D4318 | Ck. Wear & Critical Dimensions | 12 |
| Grooving Tool - T89, D4318 | Ck. Critical Dimensions | 12 |
| Hydrometers - T88, D422 | Ck. Critical Dimensions | 24 |
| Straightedge - T99, T134, T135, T136, T180, D698, D558, D559, D560, D1557 | Ck. planeness of edge | 6 |
| Weighted Foot Assembly - T176, D2419 | Ck. weight | 12 |
| CBR Annular and Slotted Weights - T193, D1883 | Ck. weight | 12 |
| CBR Penetration Piston - T193, D1883 | Ck. diameter | 12 |
| Standard Metal Specimen - T190, D2844 | Ck. outside diameter | 12 |
| Metal Follower - T190, D2844 | Ck. diameter | 12 |

FIG. 1—*Calibration and verification intervals for soil test equipment from Practice R18* [3].

ASTM E 329 Practice for Use in the Evaluation of Testing and Inspection Agencies as Used in Construction [*6*]

The following documents of the International Organization for Standardization (ISO) were also reviewed [*9*] as follows:

ISO Guide 25 General Requirements for the Competence of Calibration and Testing Laboratories

> ISO Guide 25 notes in its introduction that "Laboratories meeting the requirements of this Guide comply, for calibration and testing activities, with the relevant requirements of the ISO 9000 series of standards, including those of the model described in ISO 9002 when they are acting as suppliers producing calibration and test results."

ISO Guide 38 General Requirements for the Acceptance of Testing Laboratories
ISO Guide 39 General Requirements for the Acceptance of Inspection Bodies
ISO Guide 43 Development and Operation of Laboratory Proficiency Testing
ISO Guide 45 Guidelines for the Presentation of Test Results
ISO Guide 49 Guideline for Development of a Quality Manual for a Testing Laboratory
ISO Guide 54 Testing Laboratory Accreditation Systems-General Recommendations for the Acceptance of Accreditation Bodies
ISO Guide 55 Testing Laboratory Accreditation Systems-General Recommendations for Operation

A review of these existing standards and early experience with the AAP pointed out the following specific needs regarding quality systems in construction materials testing laboratories:

(1) definitive criteria a laboratory must follow in establishing a quality system,
(2) required components of a quality manual, and
(3) model documents that a laboratory may use to comply with quality system criteria and for preparing a quality manual.

AMRL drafted a standard responding to these needs that was processed through the AASHTO standards development process and published as Practice R18-92I [*3*].

## Scope of Practice R18

Practice R18 contains criteria and guidelines for establishing and implementing a quality system for a construction materials

(Date)

EQUIPMENT CALIBRATION RECORD

Calibrated by:________________
Date:________

Equipment:________________

Serial No:________________ Range of Calibration: 21°C

Previous Calibration Date:________ Next Due Date:________

Calibration Equipment Used: Glass Plate, Scale (0.1 lb) Calibration Procedure: See T19

Action Recommended: Repair ____ Replace ____ None ____

Other ____
Explain:________________

CALCULATIONS

Weight of bucket (a) ________ Weight of bucket filled and plate (c) ________

Weight of glass plate (b) ________ Weight of water c-(a+b) ________

CALIBRATION

$$\textit{Measured Factor} = \frac{\textit{Unit weight of water at test temperature}}{\textit{Weight of water}} = \_\_\_\_$$

FIG. 2—*Example of detailed equipment calibration record from Practice R18* [3].

(Date)

EQUIPMENT VERIFICATION RECORD

Verified By:________________ Date:________

Equipment: Oven

Identification No.:________________ Verification Frequency: 3 mo.

Previous Verification Date:________ Next Due
Date:________

Verification Equipment Used: Thermometer #1234 (50-200°C)

Verification Procedure: (See In-house Verification Procedure #6)

| Temperature Setting (°C) | Actual Reading (°C) |
|---|---|
| 100 | |
| 110 | |
| 120 | |
| 130 | |
| 140 | |
| 150 | |
| 160 | |
| 170 | |

Action Recommended: Repair ____ Replace ____ None ____

Comments:

FIG. 3—*Example of a detailed equipment verification record from Practice R18* [3].

(Date)

EQUIPMENT CALIBRATION AND VERIFICATION POLICIES AND PROCEDURES

General Policies:

1. Required equipment shall be calibrated at specified intervals following the general procedures indicated below.

2. Newly acquired equipment without manufacturer's certification and equipment that has not been calibrated or verified because it has been removed from service shall be calibrated or verified before being placed in service.

3. When any of the Unit's test equipment is overloaded, mishandled, giving results that are suspect, or is not meeting specification tolerances, the unit Supervisor shall remove it from service and clearly mark it by attaching a red ribbon or tape. The equipment shall be returned to service only after appropriate repairs are made and calibration and verification shows the equipment to function satisfactorily or to meet specification tolerances.

General Procedures:

1. The Supervisor in each Testing Unit shall maintain a file for each piece of equipment in his or her unit requiring calibration or verification. The file for each piece of equipment shall contain detailed records of calibration or verification work performed in chronological order and shall be kept in the Supervisor's office.

2. The Supervisor in each Testing Unit shall maintain a set of 12 labelled folders in his or her office - one for each month of the year. Each month's folder shall contain a partially completed calibration or verification record form for each piece of equipment requiring calibration or verification during the month indicated on the folder's label.

3. During the first week in each month, the supervisor of each test unit shall remove the partially completed record forms from the current month's folder and instruct appropriate staff to perform the necessary calibration or verification work within the next week and return the completed record forms.

4. The Supervisor shall prepare partially filled out record forms for each piece of equipment calibrated or verified that month - identifying the equipment and the next date calibration or verification work is required (Month and Year) - and file each partially filled out form in the appropriate monthly folder.

5. The Supervisor shall file each of the completed record forms in the appropriate equipment record file in chronological order.

FIG. 4—*Example of policies and procedures for maintaining equipment calibration and verification records from Practice R18* [3].

laboratory that tests soils, aggregates, bituminous materials, and portland cement concrete. The practice defines quality system as "the organizational structure, staff responsibilities, policies, standard operating procedures, and processes that when implemented assist the laboratory in achieving its quality objectives." A quality manual is defined as "a set of documents describing a laboratory's quality system."

Criteria provided in Section 5 of Practice R18 relative to the quality system are summarized in Table 1. Quality manual requirements given in Section 6 of Practice R18 are summarized in Table 2. These sections are supported by a nonmandatory appendix containing model documents that a laboratory may use to meet the various requirements. Figures 1 through 5 are examples of such documents.

## Experience with Practice R18

Practice R18 was incorporated in the AMRL Laboratory Inspection Program in Feb. 1993 and compliance will be mandatory for laboratories participating in the AAP in April 1994. Use of the practice has had positive impacts on AMRL, AAP and the laboratories participating in their programs as discussed below.

Practice R18 permits AMRL to evaluate a laboratory's quality system in a manner consistent with other aspects of its Laboratory Inspection Program where laboratory operations are evaluated against standardized procedures. Through training of AMRL staff to the requirements of the practice, a consistent approach to quality system review is being achieved. Deviations from Practice R18 found in a laboratory are given to the laboratory in a written report prepared by AMRL a short time after the inspection. The laboratory is encouraged to take action to correct the deficiencies.

AMRL is frequently contacted by laboratories with questions concerning a quality system since the concept is often new to them. While the model documents in the appendix of Practice R18 answer many of these questions, AMRL staff continue to be available as a resource to laboratories.

The use of Practice R18 ensures that AASHTO is using currently accepted procedures for evaluating testing laboratory quality systems when accrediting laboratories. The process of determining whether a laboratory is in compliance with AAP quality system criteria is simplified since the AMRL Laboratory Inspection Program is based on the practice, and laboratories need only correct deficiencies identified in the inspection report.

Laboratories had considerable difficulty setting up a quality system when the AAP was initiated in 1988 since requirements in the initial AAP Procedures Manual [*10*] were rather general in nature. For example, a laboratory was required to establish and implement an equipment calibration and verification program but was given little guidance as to how it was to be accomplished. Practice R18, which is referenced in the current AAP Procedures

(Date)

PROCEDURES RELATED TO PROFICIENCY SAMPLE TESTING AND ON-SITE INSPECTIONS

GENERAL:

It is the responsibility of the Quality Manager to review all reports pertaining to proficiency sample testing, on-site inspection and quality system evaluations and to bring poor results or differences to the attention of the appropriate unit supervisor. It is the responsibility of the unit supervisor to ensure that corrective action is taken and documented. (In some cases it may be necessary for the Quality Manager to take corrective action and prepare documentation relative to specific differences.)

Reports covering the results of proficiency sample testing and on-site inspections and quality system evaluations, and memorandums summarizing investigations and any corrective action taken shall be maintained by the Quality Manager in the Quality Manager's office.

PROFICIENCY SAMPLE TESTING:

Participation:
AMRL Soil Proficiency Sample Program
AMRL Aggregate Proficiency Sample Program
CCRL Concrete Proficiency Sample Program

Identifying Poor Results:
Any result that is beyond two standard deviations from the average value.

Procedures to follow when Poor Results Occur:
1. Determine if the Agency conducting the program correctly entered the data reported.
2. Determine if the test result obtained was properly transferred to the data sheet submitted.
3. Determine if all calculations leading to the test results obtained were correct.
4. Determine if the equipment used to perform the test meets specification requirements.
5. Determine if the procedures followed when performing the test conformed to specification requirements.
6. Take corrective action to repair or take steps to replace defective equipment or instruct the technician of the correct procedure to follow.
7. Prepare a memorandum of record summarizing the results of the investigation, identifying the cause of the poor results if determined and describing any corrective action taken.

ON SITE INSPECTIONS:

Participation:
AMRL Soils Inspection
AMRL Aggregate Inspection
CCRL Portland Cement Concrete Inspection

Procedures to follow when Deficiencies are Reported:
(Apparatus Deficiencies)
1. Determine if the equipment meets specification requirements.
2. If the equipment is found to be defective take necessary steps to repair or replace it.
3. Prepare a memorandum of record summarizing the results of the investigation and any corrective action taken.

(Procedural Deficiencies)
1. Discuss each procedural deficiency with the testing technician and review the proper procedure.
2. Observe the technician perform the test properly.
3. Prepare a memorandum of record summarizing the action taken.

(Quality System Deficiencies)
1. The Quality Manager shall review each deficiency cited by the evaluator with the responsible employee.
2. Take appropriate action.
3. Prepare a memorandum of record summarizing the action taken.

FIG. 5—*Example of procedures for responding to deficiencies resulting from proficiency sample testing and laboratory inspections from Practice R18* [3].

Manual [*11*], gives the laboratory guidance in setting up and operating a quality program.

Initially, many laboratories found that establishing a quality program was very time consuming and of little value in promoting laboratory quality. However, when fully operational, most laboratories agree that their quality system is having a positive impact on test quality. Practice R18 has eased the burden of laboratories in preparing a quality system, and there is less fear of the accreditation process.

The following observations can be made based on early experience with operation of the AASHTO Accreditation Program:

1. Once a quality system is established, it is not being adequately implemented by many laboratories. Specific problems identified by follow-up evaluation by AMRL include: (a) laboratory testing staff are not being periodically evaluated to determine if they retain the necessary competency, (b) equipment is not being calibrated and verified at the intervals specified in the quality manual, and (c) internal quality reviews are not being carried out. Laboratories are learning that they must not only have a quality system in place but it must be implemented in the time frame specified in the quality manual.

2. As would be expected, laboratories are finding a cost associ-

ated with improving their test quality. Increased costs result from requirements, such as having a designated individual responsible for quality management, periodic equipment calibration and verification activities, additional record keeping responsibilities, testing of proficiency samples, and preparing for and participating in evaluations of the laboratory by outside organizations.

3. Differences are showing up between governmental and private laboratories. Private laboratories appear to be having an easier time in complying with quality system criteria. This may be because private laboratories are subject to more external customer review with much of the documentation required by practice R18 already available. The customers of governmental laboratories are most often other branches of the parent governmental agency while customers of private laboratories are generally not related. Also, private laboratories often have a narrower scope of testing compared to governmental laboratories.

4. Because of budgetary constraints and retirements, many governmental laboratories are having to deal with decreasing staff levels causing agencies to rely on private laboratories to do testing. These agencies are placing increased reliance on accredited laboratories for testing services.

5. Large laboratories appear to have a more difficult time than smaller laboratories in preparing and implementing a quality system. This is probably a result of the broader scope of their testing activities, which requires more employees, equipment, and management oversight.

6. Increasing reliance on quality assurance/quality control (QA/QC) programs by governmental agencies is promoting the need for competent laboratories, with such competency demonstrated through accreditation. On federal aid projects, the Federal Highway Administration has been encouraging the laboratories administrating the QA/QC programs to become accredited. This includes governmental as well as private laboratories.

## Conclusion

The preparation and use of Practice R18 in the AASHTO Accreditation Program has provided laboratories with specific guidance on criteria related to quality that must be met in order to become accredited. The practice has taken generic criteria from ASTM standards, ISO Guide 25, and ISO 9000 series standards and made them specific for the fields of test included in the AAP: asphalts, soils, aggregates, bituminous concrete, and Portland cement concrete. Initial experience with use of Practice R18 indicates that while it is causing difficulties for some laboratories, benefits in improved test quality are being realized. Organizations working in other fields of testing can learn much from the work of AASHTO relative to the quality of construction materials testing laboratory.

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